Coupling of CLM3 into MM5 to Improve Snow and Dynamic Vegetation Processes

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RESEARCH OBJECTIVES

The Pennsylvania State University/ National Center for Atmospheric Research (Penn State/ NCAR) fifth-generation Mesoscale Model (MM5) has been extensively used for regional weather and climate forecasts as well as research for more than ten years. However, the snow schemes in this model are unable to produce realistic simulations for the winter and spring periods because of oversimplified snow physics (Jin and Miller, 2005a). Additionally, the prescribed vegetation parameters, such as leaf area index, significantly weaken the model's ability to predict future climate and weather. In this study, the advanced NCAR Community Land Model version 3 (CLM3), with its sophisticated snow and dynamic vegetation schemes, is incorporated into MM5 to improve its forecast and simulation capability.

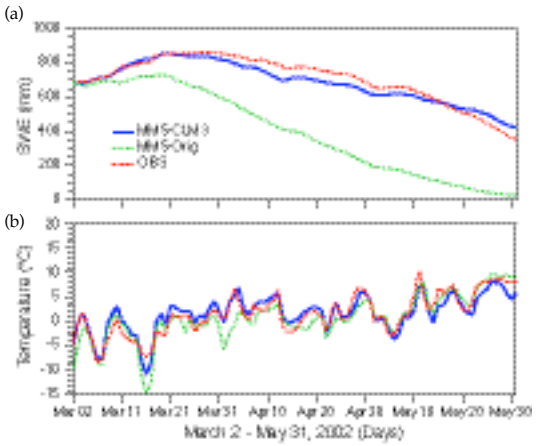

Figure 1. Comparison of simulated and observed (a) SWEs and (b) temperatures averaged over 50 SNOTEL stations in the Columbia River basin for the period of March 2 through May 3, 2002.

APPROACH

The nonhydrostatic version of MM5 is used in this study, with the Grell convection scheme adopted to parameterize cumulus clouds and the Medium Range Forecast planetary-boundary-layer scheme applied to solve boundary-layer processes. CLM3 physically describes the mass and heat transfer within the snowpack, using five snow layers that include liquid water and solid ice. Interactions among the snow, soil, and vegetation are a function of the CLM3 mass and energy equations. A sophisticated surface albedo scheme is chosen to improve the surface energy-balance simulations. Introduction of a maximum of eight subcells within each CLM3 cell strengthens the description of land-surface heterogeneity. The vegetation is dynamically generated under soil and atmospheric conditions favoring vegetation respiration and photosynthesis processes.

The coupled MM5-CLM3 was used to generate two-way, 60-km-to-20-km-resolution nested simulations. The 20 km simulation is the focus of the present analysis. The National Centers for Environmental Prediction (NCEP) Reanalysis data was used as MM5-CLM3 initial and 6-hourly-updated lateral-boundary conditions for the period of March 1 to May 31, 2002, and the model output was saved every six hours. The MM5-CLM3 performance was evaluated at the Columbia River basin for the cold season, using ground observations from an automated Snowpack Telemetry (SNOTEL) system. The SNOTEL data includes snow-water equivalent and surface air temperature.

ACCOMPLISHMENTS

Compared with the original version of MM5, the coupled MM5-CLM3 significantly improves snow and surface temperature simulations. Figure 1a shows the time series of snow-water equivalent (SWE) averaged over 50 SNOTEL stations in the Columbia River basin. The SWEs produced by MM5-CLM3 are in very good agreement with the observations, as a result of sophisticated snow physics and related model processes, while the SWEs from the original MM5 with simple snow processes are greatly underestimated. The 50-station averaged temperatures from MM5-CLM3 are also consistent with observations, but the original MM5 produces cold biases during the early simulation period, caused by the large amount of energy consumed by the faster snow melt.

SIGNIFICANCE OF FINDINGS

The coupled MM5 and CLM3 model significantly improves snow and surface air-temperature simulations. The evaluation of the dynamic vegetation scheme, using our ensemble techniques, are part of our current work and will be reported in the near future. This coupled model increases the predictability of the regional climate model and provides a reliable tool for regional weather and climate research.

RELATED PUBLICATIONS

Jin, J., and N.L. Miller, An analysis of climate variability and snowmelt mechanisms in mountainous regions. Journal of Hydrometeorology (in press), 2005a. Berkeley Lab Report LBNL-53845.

Jin, J., and N.L. Miller, Coupling of CLM3 into MM5 to improve snow simulation and dynamic vegetation processes. Journal of Hydrometeorology (submitted), 2005b.

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